Feasibility Study of Using Rice Husk and its Treated Forms with Alkali Solution as a Desiccant Material

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Abstract: The utilization of industrial and agricultural waste and byproduct and natural fibers has been attracted many researchers interest because of its economic benefits and tackling environment issue both. In this study, the feasibility of using rice husk and its treated form with alkali solution as a desiccant material has been investigated. The bare RH and treated RH have been characterized using FTIR, XRD, DSC, TGA, and SEM. The ability of water absorbance for the prepared samples has also been considered that water absorption test was carried out. The results revealed higher water absorbance of alkali treated RH compared to the bare RH. Currently, the work is focused on determining superior treatment conditions of treating RH involving more characterization methods.

Key-Words: - Agricultural wastes, Alkali treated, Desiccants, Rice Husk, Treated Rice Husk, water absorbance.

1 Introduction

To produce dried products, solar desiccant drying system has been modelled and manufactured. Solar energy as an alternative resource has become attractive significantly. The aforementioned alternative resource is considered as an environmentally friendly and permanent source of renewable energy [1]. Desiccants act is considered as moisture absorber in order to dry their surrounding environments. Drying mitigates the hazardous side effects of moisture, such as corrosion, swelling, and the development of rust, mold, mildew, and fungus. Desiccants are mainly used in electronics, food, shipping, sailing, tools, travel and relocation, and desiccant cooling systems. Several materials have been utilized as desiccants to absorb different types of liquid. Although several sorts of synthetic and inorganic exist in nature, certain types are composed of natural ingredients, such as plants. The absorbent properties of desiccants are different, and they react differently to diverse environments. Some desiccants exhibit greater affinity with oil than with water or other types of liquid materials. The majority of these materials are expensive, encouraging researchers to identify new and economic materials [2-5]. Various researchers have also studied the environmental impact of these desiccants [3]. Replacing chemical desiccants, including silica gel and molecular sieves, with natural fibres is a novel and sustainable alternative. High-fibre agricultural wastes are potential candidates as desiccants for using in desiccant-dehumidification wheels.

Ziegler et al. proposed the use of grains as desiccants in a solar-drying storage system, utilizing the deep-bed drying model [2]. Williams et al. [3] experimented the use of kenaf core as a desiccant, and compared it with silica gel to determine the suitability of the former as a packaging desiccant. Starch was determined to be suitable for industrial, commercial, and residential applications [5]. The same researchers studied the use of coconut coir as a desiccant in an engineering process [6]. There is a large amount of agricultural waste, including rice husk (RH), coconut coir, which can be effectively utilized for a sustainable approach. About 20 percent of the whole rice in the rice milling industry ended up with the production of RH as its by-product [7]. Because of economic and environmental crisis, this study emphasizes on creating products applying agricultural waste.

Besides, the study enhances substitute construction materials, minimizing the environmental and social problems. [8]. Potentially, agricultural waste may be employed as energy supply on continual searches for renewable resources of energy. Biomasses use has obtained considerable attention as it is considered a significant resource of energy. Furthermore, to be accounted as a renewable, the rice husks can be taken into account as a considerable energy resource potential, becoming a significant part of the nation's matrix of energy[9]. In comparison with other biomasses, RH contains uncommon amount of silica. Rice husks possess low bulk density [10] and consequently require high pressures to produce boards of acceptable properties. Improvement of the adhesion properties of rice husks requires modification of their physical and chemical surface properties. Chemical treatments are among the most popular methods used for the surface treatments of agricultural fibres. The most common chemical treatment method is alkali treatment. This method improves the adhesion properties of agricultural fibres by facilitating the interaction between the fibre surfaces and the matrix [11]. This study investigates the possibility of using rice husk and its treated form as a desiccant material.

2 Experimental Procedure

Rice husk was gathered from a local rice mill during milling season. First of all the rice husk was washed with deionized water and dried in an oven at 105 °C for 24 hours. The clean and dried rice husks were treated by soaking it in 1.0% (W/V) KOH solution at 100°C for 3 hr (50g rice husk in 500mL alkali solution). It was then left overnight to dry, and later filtered. The filtrated rice husks (first) were washed by HCl 0.1% (W/V) solution and later washed with plenty of distilled water until it was neutralized (pH = 7). The precipitate was then dried in the oven at 105 °C for 12 hours (Scheme. 1). The (Fig. 1) shows the procedure of filtration. The treated and untreated rice husk was tested for absorbency. . Samples of untreated and treated rice husk are selected for comparing together. The absorption water test allows a sample to draw as much liquid as it can hold. The sample is placed on water bath for various times such as 30 minutes, 1 hour and 2 hour, so the initial and final weight is recorded, the absorbed water of sample is calculated. In this way, the difference between the initial and the final weight gives the amount of water that was present in sample. The output is expressed as a percentage of the input.

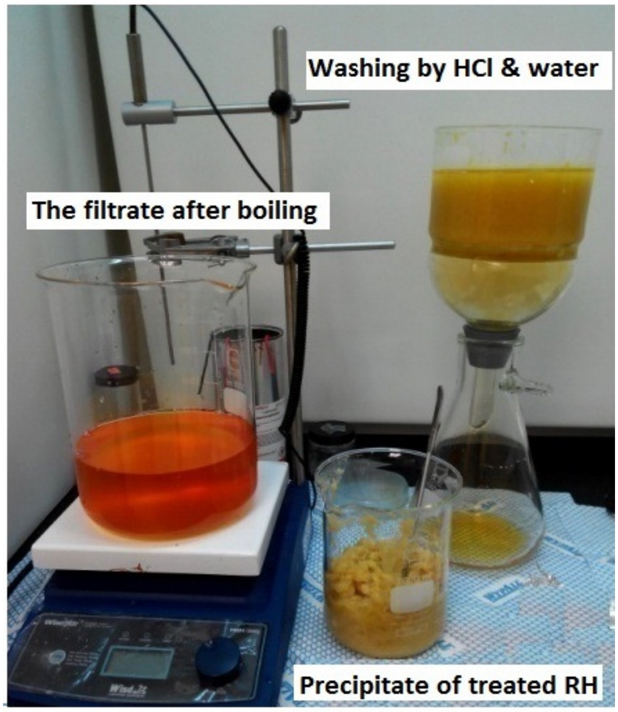
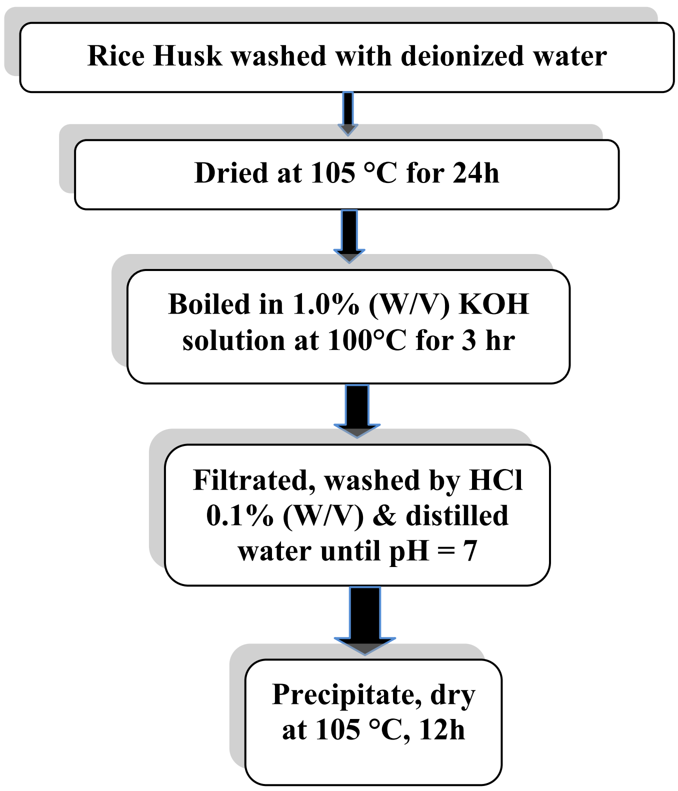


Fig. 1, Filtration of rice husk after treatment with 1.0% (W/V) KOH



(Scheme. 1)

3 Characterization

The physical appearance of untreated rice husk was seen to be brownish in color prior to treatment. After treatment, it was seen to be light-yellowish in color (See figure 2).

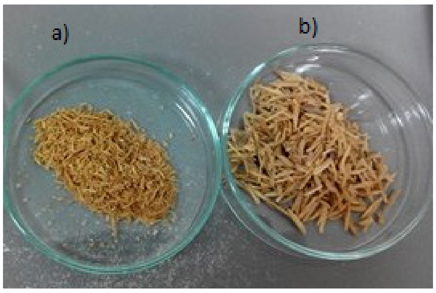


Fig. 2, (a) RH after treatment at 100°C for 3 h, RH as received without treatment (b)

Table 2 lists the chemical compositions of RH (before and after treatment) as determined by X-ray fluorescence (XRF) analysis.

Table 2, Chemical compositions of RH before and after treatment as determined by XRF (mass%)

Chemical Composition %	RH (before treatment)	RH (after treatment)
SiO2	89.14	59.79
Al_2O_3	0.29	3.22
Fe_2O_3	0.28	5.58
CaO	0.95	0.03
MgO	0.42	0.35
Na_2O	-	1.59
K_2O	4.79	2.65
SO_3	1.18	3.56
P_2O5	1.31	0.71
Cl	1.28	9.45
MnO	0.16	0.15
WO3	0.11	0.86
CoO	0.04	9.56
ZnO	0.03	0.39
CuO	-	2.23
TiO2	-	0.40
Pd	-	0.30
Ru	-	

Alkali treatment caused substantial chemical degradation of hemicelluloses, lignin, and part of the crude fibers in rice husks. The usage of 1.0% KOH eliminated lignin and hemicelluloses in alkali-treated agricultural fibers. However, it is also believed that lignin is capable of retaining its structural stability[12]. The results of chemical content analysis have demonstrated that lignin was degraded during alkali treatment, and in any case, some researchers posited that Lignin content dropped by 96% as the concentration of NaOH was increased at the same rate [13] . Albano et al. [14] used 18% NaOH, while and Rajulu et al. [15] used 2% NaOH, and both confirmed the elimination of lignin and hemicelluloses in alkali-treated agricultural fibers. The crystallinity analyses of the samples were conducted using Bruker DB-Advance X-ray Diffractometer (XRD), Germany. Figure 3 shows the XRD diffractogram of treated RH. The X-ray diffraction (XRD) pattern of treated RH was mainly more crystalline silicon oxide phase diffused in both sharp peaks. Other studies mentioned the presence of [16] a strong peak at about 21.83º 2θ angle. It can be seen that peak at Theta = 21.83 degrees, confirming the formation of crystalline silica and a little amourphous silica, with the second sharp peak detected at about 15.71º 2θ with the same specification as well. Figures 4 shows the scanning electron micrographs of the outer surfaces of untreated rice husks and rice husks treated by 1.0% KOH solutions. Scanning electron microscope was used to study the surface roughness of untreated and treated rice husks. The results showed that the outer surface of untreated rice husks is quite rough. The roughness of the outer surface is represented by the asperities (Figure 4(a)). However, the asperities were almost removed from the surface after treatment in 1.0% KOH solutions (Figure 4(b)). The effects of alkali treatments on the change of surface roughness of various agricultural fibers are widely acknowledged [11]. FESEM of Rice husk show a regular well-defined layered structure (Fig. 4), which agrees with previous study observed in vermiculite and other phyllosilicates [17]. It seems that the alkali treatment of rice husk cannot destroy the inherent structure of the husk. KOH treatment removes the SiO_2, leaving behind the fibrous organic material. Alkali treatment led to formation of holes on the rice husk, and as part of the SiO_2 is in intimate contact or bonded to the organic molecules, some silicon remains intact. The functionality groups of the samples were determined using FTIR spectra, with the results being depicted in Figure 5. Four bands represents bare and treated rice husk. Bands 1041 cm^{-1} and 793 cm^{-1} are related to O-Si-O stretching vibrations. Also, in treated rice husk, the band 1659 cm^{-1} belongs to C-O group, while the bands at 3333 cm^{-1} are due to the chemisorbed water and surface hydroxyl groups. Bands 1023 cm^{-1} and 897 cm^{-1} are related to O-Si-O stretching vibration. Differential scanning calorimetry measurements (DSC) were carried out under nitrogen, with a Thermal Analyser Instruments (Figure. 6). The peak in 81.56 °C belonged to the removal of water, the temperature of melting showed at 348.75 °C, and the peak in 427.50°C is due to temperature of crystallization. The (Figure. 7) demonstrates the findings for TGA thermo grams for treated rice husks. This reveals the influence of alkali treatment on thermal stability of the rice husks. The Initial weight loss of 5.0%, that implies to remove of water from the specimen below 150°C. At this stage, alkali treated husk degradation was continual starting from 230°C to 372°C. The decline in the thermal stability of alkali treated husks was because of the elimination of specific parts of the rice husks. According to the observation, fall in the thermal stability of the alkali treated husks may be related to the elimination of hemicelluloses and/or lignin. Nevertheless, Rowell [18], indicates that among three components including hemicelluloses, lignin, and cellulose, the lignin possesses the highest thermal stability; as a result, it degrades at higher temperatures. Thermal stability decline of alkali treated husks was not because of the elimination of hemicelluloses but lignin. Nonetheless, Shah et al. [19] reveal that the increase in thermal stability of alkali treated lignocellulosic fibres may be because of the creation of cellulose-lignin structure. Furthermore, the findings achieved indicate the thermal stability decrease of the alkali treated husks was because of the elimination of lignin.

Another physical property being considered is water absorption. In this circumstance, the percentage of water absorption rise with rice husk treatment. Because of the chemical structure and hydroxyl groups in the chain, cellulosic material tends to absorb fluid. The oxygen and hydrogen are located in the outermost surface and soak any water amount, generating a hydrogen bond. Most natural absorbents exist today are comprised of cellulosic fibres including fluff pulp, cotton, rayon, rice husk, and Kenaf core. The chemical structure has a direct influence on a product absorbency features. [20]. However, characteristics of the hydroxyl group of RH are responsible for the water absorption. The detailed measurement is currently being conducted.

Table 1 demonstrates the results of RH water absorption for two periods of before treatment and after treatment at different times. As can be clearly seen, the absorption of water rose considerably from 30 minutes to one hour; more absorption at 2 hours was not observed.

$$\%Wa = [(Wi-Wo)/Wi]*100$$

Wa : water absorption
Wi : Initial weight
Wo : Final weight

Table 1, the percentage of water absorption of RH before and after treatment

Materials	%Water absorption		
	After 30 minutes	After 1 hour	After 2 hours
Rice Husk	6.4	11.0	13.2
Treated Rice Husk	14.5	23.0	25.1

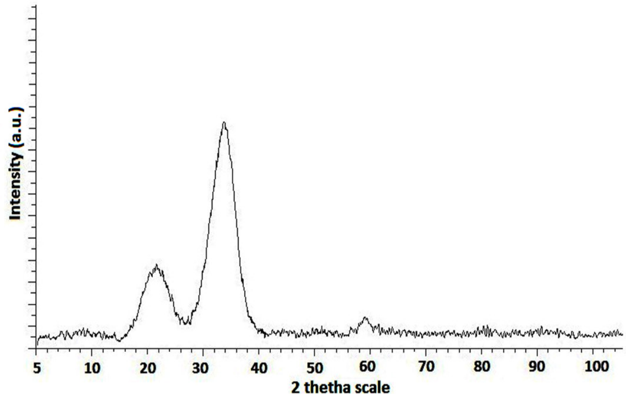


Fig. 3, XRD patterns of treated RH

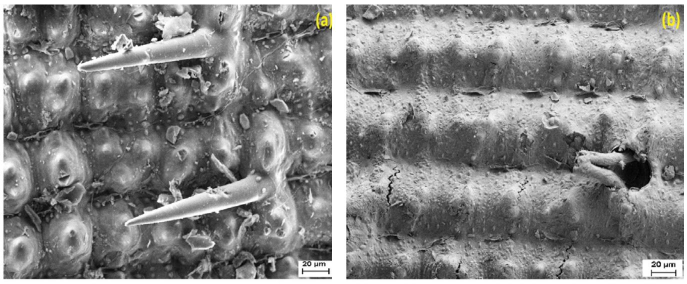


Fig. 4, FESEM photographs of a) bare rice husk b) alkali treated rice husk

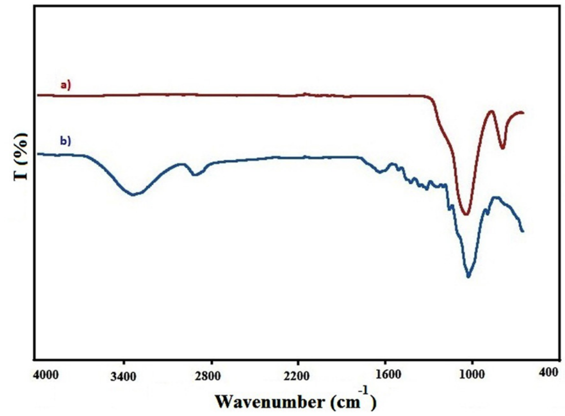


Fig. 5, FTIR spectra a) rice husk b) alkali treated rice husk by 1.0%KOH

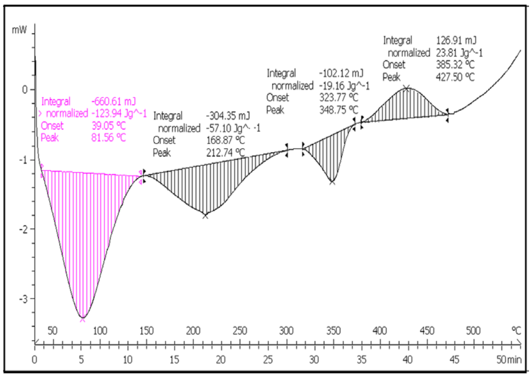


Fig. 6, DSC of alkali treated rice husk by 1.0%KOH

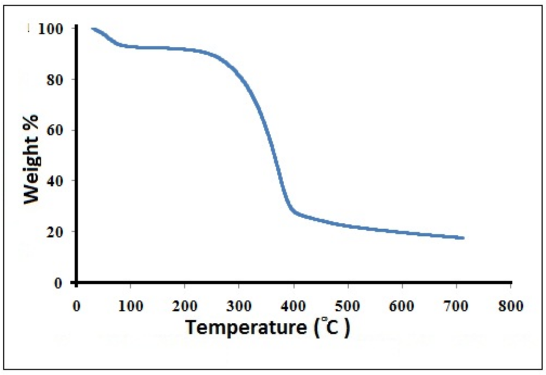


Fig. 7, TGA of alkali treated rice husk by 1.0%KOH

4 Conclusion

The initial findings in this research revealed that agricultural wastes have the potential to be used as a desiccant instead of chemical desiccants. Its granular structure, insolubility in water, chemical stability, high mechanical strength, and local availability at almost no cost of Rice husk (RH) make it popular agriculture waste for investigation. The advantage in using these adsorbents in certain critical application is the fact that there is no need to regenerate them due to their low production costs. Rice husks alkali treatment influences the thermal properties, chemical structure, and physical properties of rice husks. Rice husk treatment performed well compared to untreated rice husk. Treating the rice husk with dilute solution of 1.0% KOH improves the bond strength of O-Si-O of the silica and reduces the quantity of amorphous silica. In addition, using agricultural wastes provide additional value by preserving our environment, reducing the carbon emission, and promoting sustainable products. It should also be pointed out that prior to the general application of a proposed new concept, detailed studies involving the determination of superior treatment condition and optimization of the procedure, investigating the life cycle of the rice husk (adsorption-regeneration), and the quality of air leaving the bed, must be conducted beforehand. Application of agricultural waste materials as desiccants involve more environmentally friendly technologies for treatment and preparation, also desiccant systems using waste materials consumes less energy than systems using chemical desiccants. Our recommendations for future studies consist to consider local agricultural waste materials and Investigation of the life cycle of green desiccants.

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